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Reference 3

VIBRATION MEASURING METHOD AND VIBRATION MEASURING SYSTEM

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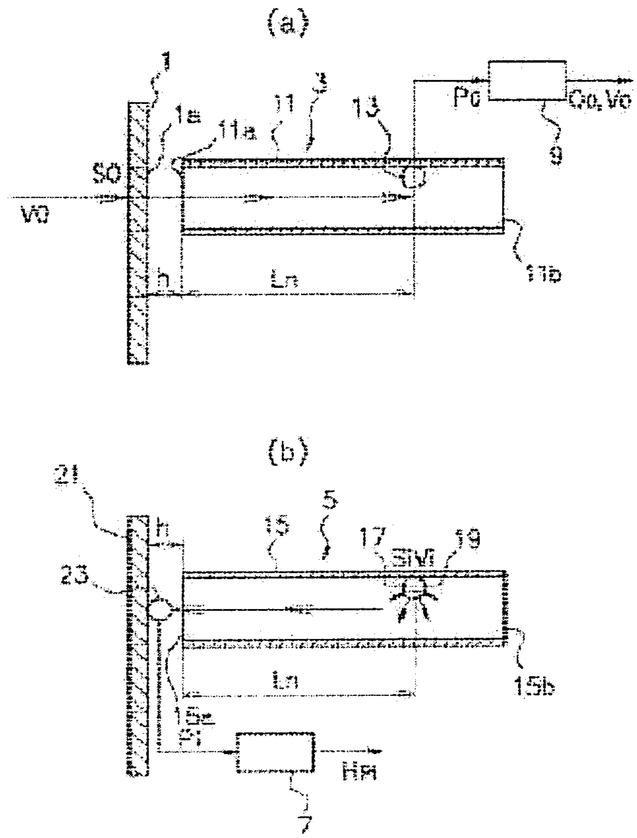
Abstract of **JP 2002195876 (A)**

PROBLEM TO BE SOLVED: To provide a non-contact vibration measuring method capable of removing the effect of sound sources near a measured surface by a simple installation and capable of performing measurement in a short time. SOLUTION: A first sound tube 11 is disposed so that its opening 11a is apart from the measured surface 1a by a distance h. The sound pressure P0 of a sound emitted from the measured surface 1a is measured in the sound tube 11 at a position apart from the opening 11a by a prescribed distance Ln. A vibration plate 17 having a prescribed area Si and vibrating at a vibration speed Vi is disposed in a second sound tube 15 capable of exhibiting a propagation characteristic nearly equal to that of the sound tube 11 at a position apart from its opening 15a by the prescribed distance Ln.; The sound pressure Pi of a sound emitted from the vibration plate 17 is measured outside the sound tube 15 at a position confronting the opening 15a and apart from the opening 15a by the prescribed distance h. A propagation characteristic HPi is calculated from the area Si, vibration speed Vi, and sound pressure Pi, according to HPi=Si&times Vi/Pi. The volume velocity Q0 of the measured surface is calculated from the propagation characteristic HPi and the sound pressure P0, according to V0= P0&times HPi.



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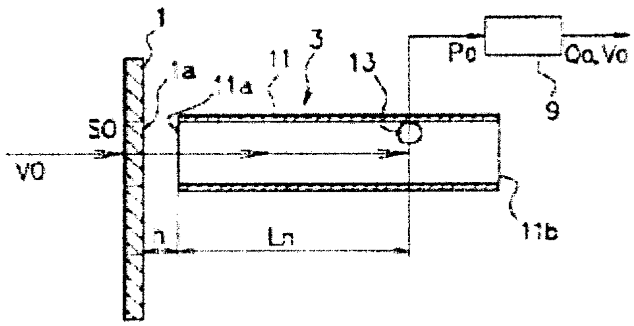
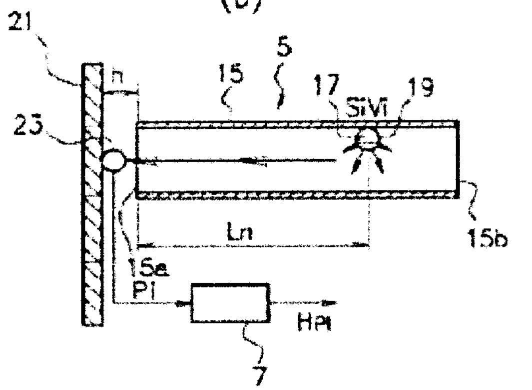
Abstract:
PROBLEM TO BE SOLVED: To provide a non-contact vibration measuring method capable of removing the effect of sound sources near a measured surface by a simple installation and capable of performing measurement in a short time.SOLUTION: A first sound tube 11 is disposed so that its opening 11a is apart from the measured surface 1a by a distance h. The sound pressure P0 of a sound emitted from the measured surface 1a is measured in the sound tube 11 at a position apart from the opening 11a by a prescribed distance Ln. A vibration plate 17 having a prescribed area Si and vibrating at a vibration speed Vi is disposed in a second sound tube 15 capable of exhibiting a propagation characteristic nearly equal to that of the sound tube 11 at a position apart from its opening 15a by the prescribed distance Ln. The sound pressure Pi of a sound emitted from the vibration plate 17 is measured outside the sound tube 15 at a position confronting the opening 15a and apart from the opening 15a by the

prescribed distance h. A propagation characteristic HPi is calculated from the area Si, vibration speed Vi, and sound pressure Pi, according to HPi=SixVi/Pi. The volume velocity Q0 of the measured surface is calculated from the propagation characteristic HPi and the sound pressure P0, according to V0= P0xHPi.

(a)



(b)



JPO Machine translation abstract:

(57) **Abstract**(Modified)
Technical problem Offer of the oscillating instrumentation method by non-contact **measurable / that the influence of the sound source near the measured plane can be eliminated with easy equipment / with a short time .**
Means for Solution The 1st sounding tube 11 is arranged so that the opening 11a may estrange only the distance h from the measured plane 1a, The sound pressure P0 of a sound emitted from the measured plane 1a in a position which estranged only the prescribed distance Ln from the opening 11a within the 1st sounding tube 11 is measured, The diaphragm 17 which has prescribed area Si and vibrates by the velocity of vibration Vi is arranged so that only the prescribed distance Ln may be estranged from the opening 15a in the 2nd sounding tube 15 that can demonstrate a propagation characteristic almost equal to the 1st sounding tube 11, The sound pressure Pi of a sound emitted from the diaphragm 17 in a position which counters with the opening 15a out of the 2nd sounding tube 15, and estranges only the prescribed distance h from the opening 15a is measured, According to Hpi=Si xVi /Pi, the propagation characteristic Hpi is computed from area Si, the velocity of vibration Vi, and the sound pressure Pi, and the volume velocity Q0 of a measured plane is computed according to V0 =P0xHpi from this propagation characteristic Hpi and the sound pressure P0.

Claim(s)
Claim 1 The 1st sounding tube that has an opening at the end is arranged so that this opening may estrange only the prescribed distance h from a measured plane, The sound pressure P0 of a sound emitted from said measured plane in a position which estranged only the prescribed distance Ln from said opening within said 1st sounding tube is measured, It arranges so that only said prescribed distance Ln may be estranged from said opening in the 2nd sounding tube that has an opening for a diaphragm which has prescribed area Si and vibrates by the velocity of vibration Vi at the end, and can demonstrate a propagation characteristic almost equal to

said 1st sounding tube, The sound pressure Pi of a sound emitted from said diaphragm in a position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening is measured, An oscillating instrumentation method computing the propagation characteristic Hpi according to following formula Hpi=Si xVi /Pi from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and computing the volume velocity Q0 of a measured plane according to following formula Q0 =P0 xHpi from said propagation characteristic Hpi and the sound pressure P0.

Claim 2 An oscillating instrumentation method which is the oscillating instrumentation method according to claim 1, and is characterized by blockading the other end of said 1st sounding tube.

Claim 3 An oscillating instrumentation method which is the oscillating instrumentation method according to claim 1 or 2, and is characterized by arranging a sound-absorbing material at least in a part on each inner skin of said 1st and 2nd sounding tubes.

Claim 4 According to following formula Hpi=Si xVi /Pi, the propagation characteristic Hpi is computed from the 2nd sound pressure measuring device characterized by comprising the following, said area Si and the velocity of vibration Vi, and the sound pressure Pi, this propagation characteristic Hpi and the sound pressure P0. from -- following following formula V0 =P0xHpi -- the volume velocity Q0 of a measured plane An oscillating instrumentation system provided with operation part to compute

The 1st sounding tube arranged so that it may have an opening at the end and this opening may estrange only the prescribed distance h from a measured plane.

The 1st sound pressure test section that measures the sound pressure P0 of a sound which is arranged in said 1st sounding tube and emitted from said measured plane so that only the prescribed distance Ln may be estranged from said opening.

The 1st sound pressure measuring device it has.

The 2nd sounding tube that has an opening at the end and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, A diaphragm which is arranged in said 2nd sounding tube, has prescribed area Si, and vibrates by the velocity of vibration Vi so that only said prescribed distance Ln may be estranged from said opening, The 2nd sound pressure test section that measures the sound pressure Pi of a sound which is arranged out of said 2nd sounding tube, and is emitted from said diaphragm so that it may counter with this opening in a position which estranged only said prescribed distance h from said opening.

Claim 5 An oscillating instrumentation system which is the oscillating instrumentation system according to claim 4, and is characterized by blockading the other end of said 1st sounding tube.

Claim 6 An oscillating instrumentation system which is the oscillating instrumentation system according to claim 4 or 5, and is characterized by arranging a sound-absorbing material at least in a part on each inner skin of said 1st and 2nd sounding tubes.

Detailed Description of the Invention

0001

Field of the Invention This invention relates to the method and device which measure surface vibration of a structure.

0002

Description of the Prior Art In order to measure vibration of a structure generally, the accelerometer is used widely. However, when vibration of a low-mass portion was measured like measurement of surface vibration of the thin gauge structure which noise tends to generate, or measurement of the plane of vibration of a loudspeaker, even if it used the small accelerometer, there was inconvenience that the mass will affect a measurement value.

0003 On the other hand, according to the technique of asking for the velocity of vibration by non-contact, it is possible to perform oscillating measurement of a low-mass portion correctly. As such a technique, the method of using a laser Doppler velocimeter (LDV), the sound intensity method, the acoustical holography method, etc. are known.

0004

Problem(s) to be Solved by the Invention Although the sound intensity method is used widely and is well known also as particle-velocity mensuration, when a strong sound source exists near the portion under test, there is a problem that a possibility that a measurement error will increase that it is easy to receive the influence is high. By the method and acoustical

holography method for using LDV, there is inconvenience that equipment is large-scale and that it is expensive, in the method of using especially LDV, it is easy to receive change of the reflectance of a portion under test, and the influence of shape, and there is also a problem that measuring time including adjusting time takes great time.
0005 This invention was made in view of the above-mentioned actual condition, and is ****. The purpose does not need equipment, but the influence of the sound source near the measured plane can be eliminated, and it is offer of the oscillating instrumentation method of the structure by non-contact **measurable with a short time** , and a ******** system.

0006
Means for Solving the Problem An oscillating instrumentation method concerning this invention that the above-mentioned purpose should be attained, The 1st sounding tube that has an opening at the end is arranged so that this opening may estrange only the prescribed distance h from a measured plane, The sound pressure P0 of a sound emitted from said measured plane in a position which estranged only the prescribed distance Ln from said opening within said 1st sounding tube is measured, It arranges so that only said prescribed distance Ln may be estranged from said opening in the 2nd sounding tube that has an opening for a diaphragm which has prescribed area Si and vibrates by the velocity of vibration Vi at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, The sound pressure Pi of a sound emitted from said diaphragm in a position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening is measured, According to following formula Hpi=Si xVi /Pi, the propagation characteristic Hpi is computed from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and the volume velocity Q0 of a measured plane is computed according to following formula V0 =P0 xHpi from this propagation characteristic Hpi and the sound pressure P0.
0007 An oscillating instrumentation system concerning this invention is provided with the following.
The 1st sound pressure measuring device.
The 2nd sound pressure measuring device.
Operation part.

0008 The 1st sounding tube arranged so that said 1st sound pressure measuring device may have an opening at the end and this opening may estrange only the prescribed distance h from a measured plane, It has the 1st sound pressure test section that measures the sound pressure P0 of a sound which is arranged in said 1st sounding tube and emitted from said measured plane so that only the prescribed distance Ln may be estranged from said opening. The 2nd sounding tube that said 2nd sound pressure measuring device has an opening at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, A diaphragm which is arranged in said 2nd sounding tube, has prescribed area Si, and vibrates by the velocity of vibration Vi so that only said prescribed distance Ln may be estranged from said opening, It has the 2nd sound pressure test section that measures the sound pressure Pi of a sound which is arranged out of said 2nd sounding tube, and is emitted from said diaphragm so that it may counter with this opening in a position which estranged only said prescribed distance h from said opening. Said operation part computes the propagation characteristic Hpi according to following formula Hpi=Si xVi /Pi from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and computes the volume velocity Q0 of a measured plane according to following formula V0 =P0 xHpi from this propagation characteristic Hpi and the sound pressure P0.
0009 According to the above-mentioned instrumentation method and the instrumentation system, the volume velocity Q0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in an outer wall of the 1st sounding tube, the radiation sound from other than a measured plane can eliminate influence of a sound source near the measured plane, and further, that it is hard to receive change of reflectance of a measured plane, and influence of shape, since adjusting time is unnecessary, it can measure it in a short time.
0010 In the above-mentioned instrumentation method and an instrumentation system, the other end of said 1st sounding tube may be blockaded. Thereby, influence of a radiation sound from other than a measured plane can be eliminated still more certainly, and the accuracy of measurement improves. The other end of the 2nd sounding tube may be blockaded similarly.
0011 In the above-mentioned instrumentation method and an instrumentation system, a

sound-absorbing material may be arranged at least to a part which it is on each inner skin of said 1st and 2nd sounding tubes. Thereby, generating of resonance is controlled in the 1st and 2nd sounding tubes, and the accuracy of measurement improves.

0012 In an aforesaid measuring method and a measurement system, it may be one sounding tube with which said 1st sounding tube and said 2nd sounding tube are common. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.

0013 As for a cross-section area of said 1st and 2nd sounding tubes, in an aforesaid measuring method and a measurement system, it is preferred to be set up smaller than area which serves as a plane wave to object upper limited frequency. Thereby, since a measured plane and a radiation sound from a diaphragm are spread, respectively, without decreasing inside of the 1st and 2nd sounding tubes, their accuracy of measurement improves.

0014 The sound pressure Pi of a sound emitted from said diaphragm on the surface of a rigid high member by position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening in an aforesaid measuring method and a measurement system may be measured, Said 1st sounding tube may be arranged along a normal line direction of said measured plane.

0015 The velocity of vibration V0 of a measured plane may be computed according to following formula V0 =Q0 / S0 from the volume velocity Q0 and the area S0 of a measured plane.

0016

Embodiment of the Invention Hereafter, one embodiment of this invention is described based on a drawing.

0017 They are a mimetic diagram showing the state where drawing 1 (a) does not have a mimetic diagram of the 1st sound pressure measuring device of this embodiment, drawing 1 (b) does not have a mimetic diagram of the 2nd sound pressure measuring device of this embodiment, and drawing 2 (a) does not have the 1st sounding tube, and a mimetic diagram showing the state where drawing 2 (b) has the 1st sounding tube.

0018 First, the basic constitution of the instrumentation system concerning this embodiment is explained.

0019 As shown in drawing 1 (a) and drawing 1 (b), the instrumentation system concerning this embodiment is provided with the following.

The 1st sound pressure measuring device 3.
The 2nd sound pressure measuring device 5.
Operation part 7 and 9.

0020 The arbitrary parting planes (measured plane) 1a of the vibrating wall 1 which is a measuring object had the prescribed area S0, and the 1st sound pressure measuring device 3 is provided with the 1st sounding tube 11 and 1st microphone (1st sound pressure test section) 13. The 1st sounding tube 11 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis, and the openings 11a and 11b which present said sectional shape are formed in the both ends. The 1st sounding tube 11 has been arranged along the normal line direction of the parting plane 1a, and the opening 11a of an end has estranged only the prescribed distance h from the parting plane 1a. The microphone 13 is arranged in the 1st sounding tube 11 so that only the prescribed distance Ln may be estranged along with a medial axis from the opening 1a, it measures the sound pressure P0 of the sound emitted from the parting plane 1a, and outputs it to the operation part 9. The operation part 9 computes and outputs the volume velocity Q0 and/or the velocity of vibration V0 by the method of mentioning later.

0021 The 2nd sound pressure measuring device 5 is provided with the following.

The 2nd sounding tube 15.
The loudspeaker 19 which has the diaphragm 17.
The rigid high support plate 21.
The 2nd microphone (2nd sound pressure test section) 23.

0022 The 2nd sounding tube 15 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis like the 1st sounding tube 11, and the openings 15a and 15b which present said sectional shape are formed in the both ends. The 2nd sounding tube 15 has shape almost equal to the 1st sounding tube 11, a size, and construction material so that a propagation characteristic almost equal to the 1st sounding tube

11 can be demonstrated. As long as the state where insulation is very high is acquired necessarily identically as for these elements, both construction material may be different.
0023 The diaphragm 17 is arranged in the 2nd sounding tube 15 so that only the prescribed distance Ln may be estranged along with a medial axis from the opening 15a of an end. The diaphragm 17 has prescribed area Si and vibrates by the velocity of vibration Vi. The support plate 21 is arranged almost vertically to the medial axis of the 2nd sounding tube 15 at the position which counters with the opening 15a out of the 2nd sounding tube 15, and estranges only the prescribed distance h from the opening 15a. It is fixed on the outside surface of the support plate 21 in the position which estranged only the prescribed distance h from the opening 15a, and the microphone 23 measures the sound pressure Pi of the sound emitted from the diaphragm 17, and outputs it to the operation part 7. The operation part 7 computes and outputs the propagation characteristic Hpi by the method of mentioning later.
0024 Thus, the 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5 are constituted equivalent about the propagation characteristic of a sound.
0025 Next, the instrumentation method concerning this embodiment is explained.
0026 The 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5, Since it is constituted equivalent about the propagation characteristic of a sound, the volume velocity Q0 of a reciprocity theorem to the parting plane 1a, The relation of a following formula (1) is materialized between the sound pressure P0 detected with the microphone 13, the volume velocity Qi of the diaphragm 17, the sound pressure Pi detected with the microphone 23, and the propagation characteristic Hpi.
0027Q0 / P0 =Qi /Pi =Hpi -- (1)
Here, as for the volume velocity Q0, the area S0 and the velocity of vibration V0 of the parting plane 1a ask for the volume velocity Qi by area Si and the velocity of vibration Vi of the diaphragm 17 according to a following formula (2) and (3), respectively.
0028Q0 =S0 xV0 -- (2)
Qi =Si xVi -- (3)
Therefore, the following formula (4), (5), and (6) is called for from a formula (1), (2), and (3).
0029 Hpi=Si xVi /Pi -- (4)
Q0 =P0 xHpi -- (5)
V0 =P0 xHpi/S0 -- (6)
When measuring the volume velocity Q0 and/or the velocity of vibration V0 of a sound which are emitted from the parting plane 1a, first, the 2nd sound pressure measuring device 5 is used, the sound pressure Pi of the sound emitted from the loudspeaker 19 (diaphragm 17) is detected with the microphone 23, and it is inputted into the operation part 7. Area Si and the velocity of vibration Vi of the diaphragm 17 are beforehand inputted into the operation part 7, and are memorized, and the propagation characteristic Hpi is computed according to a formula (4) from these **Pi** , Si, and Vi.
0030 Next, the 1st sound pressure measuring device 3 is used, the sound pressure P0 of the sound emitted from the parting plane 1a is detected with the microphone 13, and it is inputted into the operation part 9. The propagation characteristic Hpi computed by the operation part 7 and the area S0 of the parting plane 1a are beforehand inputted into the operation part 9, and are memorized, and the volume velocity Q0 and/or the velocity of vibration V0 of the parting plane 1a are computed according to these **P0** , Hpi, and S0 to a formula (5) and/or (6). When only the volume velocity Q0 is computed, the area S0 of the parting plane 1a does not need to be inputted into the operation part 9.
0031 According to such an instrumentation method and an instrumentation system, it can ask for the volume velocity Q0 and/or the velocity of vibration V0 of the parting plane 1a by a noncontact state from the parting plane 1a.
0032 Since a large device is not included on structure, large-scale equipment is not needed.
0033 The radiation sound from other than parting plane 1a is reflected in the outer wall of the 1st sounding tube 11. For example, if sound pressure Pm near the parting plane 1a is measured with the microphone 25 in the state where the 1st sounding tube 11 is not formed as shown in drawing 2 (a), sound pressure Pm detected will be influenced by leak lump of the oscillating radiation sound Pj from an adjoining parting plane. For this reason, detection of the radiation sound only from the parting plane 1a which is a measuring object is difficult. On the other hand, as shown in drawing 2 (b), where the 1st sounding tube 11 is formed. It is reflected in the outer wall of the 1st sounding tube 11, and the radiation sound from other than parting plane 1a is spread inside the sounding tube 11 by only the plane wave according to the velocity of vibration V0 of the parting plane 1a, and can measure the sound pressure P0 with the microphone 11.

That is, the influence of the sound source near the parting plane 1a can be eliminated.
0034 That it is hard to receive change of the reflectance of a measured plane (parting plane 1a), and the influence of shape, since adjusting time is unnecessary, it can measure extremely in a short time.
0035 The sectional shape in particular of the 1st sounding tube 11 and the 2nd sounding tube 15 is not limited, and shape with various circular, rectangles, etc. may be applied.
0036 The 1st sounding tube 11 and 2nd sounding tube 15 may be one common sounding tube. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.
0037 The cross-section area of the 1st and 2nd sounding tubes 11 and 15, It is preferred that the sectional shape of being set up smaller than the area which serves as a plane wave to object upper limited frequency, for example, the inner skin of the 1st and 2nd sounding tubes 11 and 15, is set as the size and shape which contain thoroughly the shape almost equal to a periphery edge or this shape of the parting plane 1a inside. Thereby, since the parting plane 11a and the radiation sound from the diaphragm 17 are spread, respectively, without decreasing the inside of the 1st and 2nd sounding tubes 11 and 15, their accuracy of measurement improves.
0038 By sticking and arranging the sound-absorbing material 27 on each inner skin of the 1st and 2nd sounding tubes 11 and 15, generating of resonance is controlled in the 1st and 2nd sounding tubes 11 and 15, and the accuracy of measurement improves. It is demonstrated even if the depressor effect of resonance is not established throughout each inner skin of the 1st and 2nd sounding tubes 11 and 15, For example, if it provides in the field of a semicircle as shown in drawing 3 (a) when the sounding tubes 11 and 15 are cylindrical, the effect will fully be acquired, and if it provides throughout one inner surface among four inner surfaces as shown in drawing 3 (b) when it is rectangular cylinder form, the effect will fully be acquired. Since the composition of the 2nd sounding tube 15 is almost the same as that of the 1st sounding tube 11, the graphic display is omitted.
0039 By blockading the other end 11b of the 1st sounding tube 11, the influence of the radiation sound from other than parting plane 1a can be eliminated still more certainly, and the accuracy of measurement improves. In this case, although it is also possible to blockade the other end 11b by the sounding tube 11, the lid formed in one, etc., it is most preferred for it to be more desirable to blockade with the sound-absorbing material 29, as shown in drawing 4, and to provide with the sound-absorbing material 27 on inner skin further. Also in the 2nd sounding tube 15, influence can be eliminated from the exterior by blockading similarly the other end 15b of the 2nd sounding tube 15.
0040 Next, the conducted experiment using the instrumentation system concerning this embodiment is explained.
0041 As shown in drawing 5 (a), in the 1st sound pressure measuring device 3 used in the experiment, the vibrating wall 1 which is a noise source is formed in the shape of a rectangular plate object of a 2-mm-thick griddle, and is being fixed to the buck 31. The buck 31 is formed in the shape of **which has an open face on the whole surface** a box, and it is arranged so that an open face may be horizontally suitable. The vibrating wall 1 is concluded by the edge part of the open face with two or more bolts so that the open face of the buck 31 may be blockaded. The loudspeaker 33 is being fixed on the field which carries out for relativity to the vibrating wall 1 in the buck 31. The buck 31 is formed of the griddle which has 10 sufficient mm in thickness so that the sound emitted from the loudspeaker 33 may be emitted by sound excitation only from the vibrating wall 1. 20 division (four rows by five rows) of the outside surface of the vibrating wall 1 which is a sound source is carried out, and the one parting plane 1a is set as the approximately square of 80 mm x 80 mm.
0042 The 1st sounding tube 11 is formed in the shape of **which has sectional shape and a size almost equal to the parting plane 1a** a rectangle barrel, and is attached to the traverse device besides a graphic display. The traverse device is supporting the 1st sounding tube 11 to the parting plane 1a, enabling free movement in a parallel direction and a vertical direction, where the normal line direction of the outside surface (parting plane 1a) of the vibrating wall 1 is met. Length L of the sounding tube 11 is set as 40 mm so that the sound pressure in the sounding tube 11 may not be influenced by surroundings lump. The distance Ln from the opening 11a of the sounding tube 11 to the microphone 13 is set as 30 mm so that the radiation sound from the vibrating wall 1 (parting plane 1a) may serve as a plane wave certainly.

0043 Measurement of the radiation sound from the vibrating wall 1 moved the 1st sounding tube 11 to each parting plane 1a with a traverse device, and was performed by measuring the sound pressure Pi in the sounding tube 11 with the microphone 13 on the basis of the input voltage E from the power amplification 39 to the loudspeaker 33. Under the present circumstances, the position of the sounding tube 11 to each parting plane 1a was adjusted so that the sounding tube 11 might be arranged along the normal line direction of each parting plane 1a and the opening 11a of the end of the sounding tube 11 might estrange only the prescribed distance h from each parting plane 1a. About this distance h, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0044 Simultaneously, for comparison with the result obtained by this experiment, the reflection type besides a graphic display was stuck on each parting plane 1a, and the velocity of vibration was measured, adjusting an optic axis to each parting plane 1a of every using the noncontact laser vibration meter (LDV) 37. LDV37 was used in order to eliminate the influence of the mass by an accelerometer.

0045 As shown in drawing 5 (b), in the 2nd sound pressure measuring device 5 used for the experiment, the support plate 21 is formed with iron material with a thickness of 30 mm which has sufficient rigidity. The microphone 23 is embedded at the support plate 21 so that it may be located on the outside surface of the support plate 21 in which the sound-collecting part carries out for relativity to the opening 15a of the end of the 2nd sounding tube 15. The 2nd sounding tube 15 has the 1st size and shape almost equal to the sounding tube 11, and it is arranged so that the normal line direction of opposite Perilla frutescens (L.) Britton var. crispa (Thunb.) Decne. may be met at the support plate 21. The area of the diaphragm besides the graphic display of the loudspeaker 19 in the 2nd sounding tube 15 is beforehand set as the prescribed area S0.

0046 Measurement of the radiation sound from the loudspeaker 19 was performed by measuring the sound pressure P0 of the radiation sound from the loudspeaker 19 with the microphone 23 on the basis of the input voltage e from the power amplification 43 to the loudspeaker 19. About the distance h along said normal line direction of the microphone 23 and the opening 15a of the sounding tube 15, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0047 Simultaneously, it measured by LDV besides a graphic display of the velocity of vibration V0 of the diaphragm besides the graphic display in the loudspeaker 19. Having used LDV has the dramatically small mass of a diaphragm, and it is easy to generate partial vibration and rolling in response to the influence by the weight in a contact type.

0048 The sound pressure Pi of the radiation sound from the loudspeaker 19 measured with the microphone 23 is inputted into the high speed operation device (FFT) 41 as the operation part 7. The velocity of vibration Vi measured by the area Si and LDV of the diaphragm 17 is beforehand inputted into FFT41, and is memorized, and the propagation characteristic Hpi is computed and outputted to it at each distance h of every according to said formula (4) from Pi, Si, and Vi.

0049 The sound pressure P0 of the radiation sound from the parting plane 1a measured with the microphone 13 of the 1st sound pressure measuring device 3 is inputted into the high speed operation device (FFT) 35 as the operation part 9. The propagation characteristic Hpi computed by FFT41 and the area S0 of the parting plane 1a are beforehand inputted into FFT35, and are memorized, The volume velocity Q0 is computed by every parting plane 1a according to these **P0** , Hpi, and S0 to said formula (5) and/or (6), and the aggregate value sigmaQ0 is outputted eventually. The velocity of vibration measured by LDV37 is also inputted into FFT35. In FFT35, by multiplying the velocity of vibration measured by LDV37 by the area S0 of the parting plane 1a, the theoretical value of the volume velocity in this experiment is computed by every parting plane 1a, and the aggregate value sigmaQt is outputted eventually.

0050 Next, the result of this experiment is explained based on drawing 6 - drawing 9.

0051 The propagation characteristic Hp of each distance h of every **which was outputted from FFT41** is expressed to drawing 6. It was checked that a level also increases, when the frequency characteristic showed the identical trend and its distance h increased, although there was a level difference by the distance h as shown in drawing 6.

0052 The aggregate value (experimental value) sigmaQ0 of the volume velocity characteristic computed in drawing 7 - drawing 9 at every parting plane 1a using the above-mentioned expression of relations (5) based on a reciprocity theorem, Aggregate value (theoretical value) sigmaQn of the volume velocity characteristic for which every parting plane 1a was asked from the velocity of vibration measured directly is similarly expressed with LDV37 to each distance

(h= 1 mm, 5 mm, 15 mm) of every **between the rectangular vibrating wall 1 and the sounding tube 11 which are sound sources** . In drawing 7 - drawing 9, the experimental value sigmaQ0 is a dashed line, and theoretical-value sigmaQn is expressed as the solid line, respectively.

0053 In this experiment, it was checked that the measuring time for calculating the experimental value sigmaQ0 can be shortened about to 1/5 compared with the measuring time (measuring time for calculating theoretical-value sigmaQn) which used LDV37.

0054 As shown in drawing 7, in the case of h= 1 mm of distance, each peak and a level were in agreement good to 1 kHz, and it was checked that the difference is less than about **3 dB.

0055 As shown in drawing 8, in the case of h= 5-mm distance, there was a difference of 4-5 dB below 300 Hz, but in other fields, it was checked to 1 kHz that the difference is less than about **3 dB.

0056 As shown in drawing 9, in the case of h= 15-mm distance, the peak up to 1 kHz was mostly in agreement, but on the whole, the level produced a difference of +5-+10 dB, and it was checked that especially the difference in 500 Hz or less is large.

0057 It was checked by the above experimental result by the reciprocity theorem that the propagation characteristic Hpi which includes the sounding tube 15 from the vibrating wall 1 can be searched for with sufficient accuracy by the simple method using the sounding tube 15 and the microphone 23.

0058 It was checked by using the propagation characteristic Hpi searched for and the sound pressure P0 measured with the sounding tube 11 that it can ask for the volume velocity characteristic of a vibrating structure with sufficient accuracy simple.

0059

Effect of the Invention As explained above, according to the instrumentation method and instrumentation system concerning this invention, the volume velocity Q0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in the outer wall of the 1st sounding tube, the radiation sound from other than a measured plane can eliminate the influence of the sound source near the measured plane, and further, that it is hard to receive change of the reflectance of a measured plane, and the influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

Field of the Invention This invention relates to the method and device which measure surface vibration of a structure.

Description of the Prior Art In order to measure vibration of a structure generally, the accelerometer is used widely. However, when vibration of a low-mass portion was measured like measurement of surface vibration of the thin gauge structure which noise tends to generate, or measurement of the plane of vibration of a loudspeaker, even if it used the small accelerometer, there was inconvenience that the mass will affect a measurement value.

0003 On the other hand, according to the technique of asking for the velocity of vibration by non-contact, it is possible to perform oscillating measurement of a low-mass portion correctly. As such a technique, the method of using a laser Doppler velocimeter (LDV), the sound intensity method, the acoustical holography method, etc. are known.

Effect of the Invention As explained above, according to the instrumentation method and instrumentation system concerning this invention, the volume velocity Q0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in the outer wall of the 1st sounding tube, the radiation sound from other than a measured plane can eliminate the influence of the sound source near the measured plane, and further, that it is hard to receive change of the reflectance of a measured plane, and the influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

Problem(s) to be Solved by the Invention Although the sound intensity method is used widely and is well known also as particle-velocity mensuration, when a strong sound source exists near the portion under test, there is a problem that a possibility that a measurement error will increase that it is easy to receive the influence is high. By the method and acoustical holography method for using LDV, there is inconvenience that equipment is large-scale and that it is expensive, in the method of using especially LDV, it is easy to receive change of the reflectance of a portion under test, and the influence of shape, and there is also a problem that measuring time including adjusting time takes great time.
0005 This invention was made in view of the above-mentioned actual condition, and is ****. The purpose does not need equipment, but the influence of the sound source near the measured plane can be eliminated, and it is offer of the oscillating instrumentation method of the structure by non-contact **measurable with a short time** , and a ******** system.

Means for Solving the Problem An oscillating instrumentation method concerning this invention that the above-mentioned purpose should be attained, The 1st sounding tube that has an opening at the end is arranged so that this opening may estrange only the prescribed distance h from a measured plane, The sound pressure P0 of a sound emitted from said measured plane in a position which estranged only the prescribed distance Ln from said opening within said 1st sounding tube is measured, It arranges so that only said prescribed distance Ln may be estranged from said opening in the 2nd sounding tube that has an opening for a diaphragm which has prescribed area Si and vibrates by the velocity of vibration Vi at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, The sound pressure Pi of a sound emitted from said diaphragm in a position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening is measured, According to following formula Hpi=Si xVi /Pi, the propagation characteristic Hpi is computed from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and the volume velocity Q0 of a measured plane is computed according to following formula V0 =P0 xHpi from this propagation characteristic Hpi and the sound pressure P0.
0007 An oscillating instrumentation system concerning this invention is provided with the following.
The 1st sound pressure measuring device.
The 2nd sound pressure measuring device.
Operation part.

0008 The 1st sounding tube arranged so that said 1st sound pressure measuring device may have an opening at the end and this opening may estrange only the prescribed distance h from a measured plane, It has the 1st sound pressure test section that measures the sound pressure P0 of a sound which is arranged in said 1st sounding tube and emitted from said measured plane so that only the prescribed distance Ln may be estranged from said opening. The 2nd sounding tube that said 2nd sound pressure measuring device has an opening at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, A diaphragm which is arranged in said 2nd sounding tube, has prescribed area Si, and vibrates by the velocity of vibration Vi so that only said prescribed distance Ln may be estranged from said opening, It has the 2nd sound pressure test section that measures the sound pressure Pi of a sound which is arranged out of said 2nd sounding tube, and is emitted from said diaphragm so that it may counter with this opening in a position which estranged only said prescribed distance h from said opening. Said operation part computes the propagation characteristic Hpi according to following formula Hpi=Si xVi /Pi from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and computes the volume velocity Q0 of a measured plane according to following formula V0 =P0 xHpi from this propagation characteristic Hpi and the sound pressure P0.
0009 According to the above-mentioned instrumentation method and the instrumentation system, the volume velocity Q0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in an outer wall of the 1st sounding tube, the radiation sound from

other than a measured plane can eliminate influence of a sound source near the measured plane, and further, that it is hard to receive change of reflectance of a measured plane, and influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

0010 In the above-mentioned instrumentation method and an instrumentation system, the other end of said 1st sounding tube may be blockaded. Thereby, influence of a radiation sound from other than a measured plane can be eliminated still more certainly, and the accuracy of measurement improves. The other end of the 2nd sounding tube may be blockaded similarly.

0011 In the above-mentioned instrumentation method and an instrumentation system, a sound-absorbing material may be arranged at least to a part which it is on each inner skin of said 1st and 2nd sounding tubes. Thereby, generating of resonance is controlled in the 1st and 2nd sounding tubes, and the accuracy of measurement improves.

0012 In an aforesaid measuring method and a measurement system, it may be one sounding tube with which said 1st sounding tube and said 2nd sounding tube are common. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.

0013 As for a cross-section area of said 1st and 2nd sounding tubes, in an aforesaid measuring method and a measurement system, it is preferred to be set up smaller than area which serves as a plane wave to object upper limited frequency. Thereby, since a measured plane and a radiation sound from a diaphragm are spread, respectively, without decreasing inside of the 1st and 2nd sounding tubes, their accuracy of measurement improves.

0014 The sound pressure Pi of a sound emitted from said diaphragm on the surface of a rigid high member by position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening in an aforesaid measuring method and a measurement system may be measured, Said 1st sounding tube may be arranged along a normal line direction of said measured plane.

0015 The velocity of vibration V0 of a measured plane may be computed according to following formula V0 =Q0 / S0 from the volume velocity Q0 and the area S0 of a measured plane.

0016

Embodiment of the Invention Hereafter, one embodiment of this invention is described based on a drawing.

0017 They are a mimetic diagram showing the state where drawing 1 (a) does not have a mimetic diagram of the 1st sound pressure measuring device of this embodiment, drawing 1 (b) does not have a mimetic diagram of the 2nd sound pressure measuring device of this embodiment, and drawing 2 (a) does not have the 1st sounding tube, and a mimetic diagram showing the state where drawing 2 (b) has the 1st sounding tube.

0018 First, the basic constitution of the instrumentation system concerning this embodiment is explained.

0019 As shown in drawing 1 (a) and drawing 1 (b), the instrumentation system concerning this embodiment is provided with the following.

The 1st sound pressure measuring device 3.
The 2nd sound pressure measuring device 5.
Operation part 7 and 9.

0020 The arbitrary parting planes (measured plane) 1a of the vibrating wall 1 which is a measuring object had the prescribed area S0, and the 1st sound pressure measuring device 3 is provided with the 1st sounding tube 11 and 1st microphone (1st sound pressure test section) 13. The 1st sounding tube 11 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis, and the openings 11a and 11b which present said sectional shape are formed in the both ends. The 1st sounding tube 11 has been arranged along the normal line direction of the parting plane 1a, and the opening 11a of an end has estranged only the prescribed distance h from the parting plane 1a. The microphone 13 is arranged in the 1st sounding tube 11 so that only the prescribed distance Ln may be estranged along with a medial axis from the opening 1a, it measures the sound pressure P0 of the sound emitted from the parting plane 1a, and outputs it to the operation part 9. The operation part 9 computes and outputs the volume velocity Q0 and/or the velocity of vibration V0 by the method of mentioning later.

0021 The 2nd sound pressure measuring device 5 is provided with the following.

The 2nd sounding tube 15.
The loudspeaker 19 which has the diaphragm 17.

The rigid high support plate 21.
The 2nd microphone (2nd sound pressure test section) 23.

0022 The 2nd sounding tube 15 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis like the 1st sounding tube 11, and the openings 15a and 15b which present said sectional shape are formed in the both ends. The 2nd sounding tube 15 has shape almost equal to the 1st sounding tube 11, a size, and construction material so that a propagation characteristic almost equal to the 1st sounding tube 11 can be demonstrated. As long as the state where insulation is very high is acquired necessarily identically as for these elements, both construction material may be different.
0023 The diaphragm 17 is arranged in the 2nd sounding tube 15 so that only the prescribed distance Ln may be estranged along with a medial axis from the opening 15a of an end. The diaphragm 17 has prescribed area Si and vibrates by the velocity of vibration Vi. The support plate 21 is arranged almost vertically to the medial axis of the 2nd sounding tube 15 at the position which counters with the opening 15a out of the 2nd sounding tube 15, and estranges only the prescribed distance h from the opening 15a. It is fixed on the outside surface of the support plate 21 in the position which estranged only the prescribed distance h from the opening 15a, and the microphone 23 measures the sound pressure Pi of the sound emitted from the diaphragm 17, and outputs it to the operation part 7. The operation part 7 computes and outputs the propagation characteristic Hpi by the method of mentioning later.
0024 Thus, the 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5 are constituted equivalent about the propagation characteristic of a sound.
0025 Next, the instrumentation method concerning this embodiment is explained.
0026 The 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5, Since it is constituted equivalent about the propagation characteristic of a sound, the volume velocity Q0 of a reciprocity theorem to the parting plane 1a, The relation of a following formula (1) is materialized between the sound pressure P0 detected with the microphone 13, the volume velocity Qi of the diaphragm 17, the sound pressure Pi detected with the microphone 23, and the propagation characteristic Hpi.
0027$Q0 / P0 = Qi / Pi = Hpi$ -- (1)
Here, as for the volume velocity Q0, the area S0 and the velocity of vibration V0 of the parting plane 1a ask for the volume velocity Qi by area Si and the velocity of vibration Vi of the diaphragm 17 according to a following formula (2) and (3), respectively.
0028$Q0 = S0 \times V0$ -- (2)
$Qi = Si \times Vi$ -- (3)
Therefore, the following formula (4), (5), and (6) is called for from a formula (1), (2), and (3).
0029$Hpi = Si \times Vi / Pi$ -- (4)
$Q0 = P0 \times Hpi$ -- (5)
$V0 = P0 \times Hpi / S0$ -- (6)
When measuring the volume velocity Q0 and/or the velocity of vibration V0 of a sound which are emitted from the parting plane 1a, first, the 2nd sound pressure measuring device 5 is used, the sound pressure Pi of the sound emitted from the loudspeaker 19 (diaphragm 17) is detected with the microphone 23, and it is inputted into the operation part 7. Area Si and the velocity of vibration Vi of the diaphragm 17 are beforehand inputted into the operation part 7, and are memorized, and the propagation characteristic Hpi is computed according to a formula (4) from these **Pi** , Si, and Vi.
0030 Next, the 1st sound pressure measuring device 3 is used, the sound pressure P0 of the sound emitted from the parting plane 1a is detected with the microphone 13, and it is inputted into the operation part 9. The propagation characteristic Hpi computed by the operation part 7 and the area S0 of the parting plane 1a are beforehand inputted into the operation part 9, and are memorized, and the volume velocity Q0 and/or the velocity of vibration V0 of the parting plane 1a are computed according to these **P0** , Hpi, and S0 to a formula (5) and/or (6). When only the volume velocity Q0 is computed, the area S0 of the parting plane 1a does not need to be inputted into the operation part 9.
0031 According to such an instrumentation method and an instrumentation system, it can ask for the volume velocity Q0 and/or the velocity of vibration V0 of the parting plane 1a by a noncontact state from the parting plane 1a.
0032 Since a large device is not included on structure, large-scale equipment is not needed.
0033 The radiation sound from other than parting plane 1a is reflected in the outer wall of the 1st sounding tube 11. For example, if sound pressure Pm near the parting plane 1a is measured

with the microphone 25 in the state where the 1st sounding tube 11 is not formed as shown in drawing 2 (a), sound pressure Pm detected will be influenced by leak lump of the oscillating radiation sound Pj from an adjoining parting plane. For this reason, detection of the radiation sound only from the parting plane 1a which is a measuring object is difficult. On the other hand, as shown in drawing 2 (b), where the 1st sounding tube 11 is formed. It is reflected in the outer wall of the 1st sounding tube 11, and the radiation sound from other than parting plane 1a is spread inside the sounding tube 11 by only the plane wave according to the velocity of vibration V0 of the parting plane 1a, and can measure the sound pressure P0 with the microphone 11. That is, the influence of the sound source near the parting plane 1a can be eliminated.
0034 That it is hard to receive change of the reflectance of a measured plane (parting plane 1a), and the influence of shape, since adjusting time is unnecessary, it can measure extremely in a short time.
0035 The sectional shape in particular of the 1st sounding tube 11 and the 2nd sounding tube 15 is not limited, and shape with various circular, rectangles, etc. may be applied.
0036 The 1st sounding tube 11 and 2nd sounding tube 15 may be one common sounding tube. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.
0037 The cross-section area of the 1st and 2nd sounding tubes 11 and 15, It is preferred that the sectional shape of being set up smaller than the area which serves as a plane wave to object upper limited frequency, for example, the inner skin of the 1st and 2nd sounding tubes 11 and 15, is set as the size and shape which contain thoroughly the shape almost equal to a periphery edge or this shape of the parting plane 1a inside. Thereby, since the parting plane 11a and the radiation sound from the diaphragm 17 are spread, respectively, without decreasing the inside of the 1st and 2nd sounding tubes 11 and 15, their accuracy of measurement improves.
0038 By sticking and arranging the sound-absorbing material 27 on each inner skin of the 1st and 2nd sounding tubes 11 and 15, generating of resonance is controlled in the 1st and 2nd sounding tubes 11 and 15, and the accuracy of measurement improves. It is demonstrated even if the depressor effect of resonance is not established throughout each inner skin of the 1st and 2nd sounding tubes 11 and 15, For example, if it provides in the field of a semicircle as shown in drawing 3 (a) when the sounding tubes 11 and 15 are cylindrical, the effect will fully be acquired, and if it provides throughout one inner surface among four inner surfaces as shown in drawing 3 (b) when it is rectangular cylinder form, the effect will fully be acquired. Since the composition of the 2nd sounding tube 15 is almost the same as that of the 1st sounding tube 11, the graphic display is omitted.
0039 By blockading the other end 11b of the 1st sounding tube 11, the influence of the radiation sound from other than parting plane 1a can be eliminated still more certainly, and the accuracy of measurement improves. In this case, although it is also possible to blockade the other end 11b by the sounding tube 11, the lid formed in one, etc., it is most preferred for it to be more desirable to blockade with the sound-absorbing material 29, as shown in drawing 4, and to provide with the sound-absorbing material 27 on inner skin further. Also in the 2nd sounding tube 15, influence can be eliminated from the exterior by blockading similarly the other end 15b of the 2nd sounding tube 15.
0040 Next, the conducted experiment using the instrumentation system concerning this embodiment is explained.
0041 As shown in drawing 5 (a), in the 1st sound pressure measuring device 3 used in the experiment, the vibrating wall 1 which is a noise source is formed in the shape of a rectangular plate object of a 2-mm-thick griddle, and is being fixed to the buck 31. The buck 31 is formed in the shape of **which has an open face on the whole surface** a box, and it is arranged so that an open face may be horizontally suitable. The vibrating wall 1 is concluded by the edge part of the open face with two or more bolts so that the open face of the buck 31 may be blockaded. The loudspeaker 33 is being fixed on the field which carries out for relativity to the vibrating wall 1 in the buck 31. The buck 31 is formed of the griddle which has 10 sufficient mm in thickness so that the sound emitted from the loudspeaker 33 may be emitted by sound excitation only from the vibrating wall 1. 20 division (four rows by five rows) of the outside surface of the vibrating wall 1 which is a sound source is carried out, and the one parting plane 1a is set as the approximately square of 80 mm x 80 mm.
0042 The 1st sounding tube 11 is formed in the shape of **which has sectional shape and a size almost equal to the parting plane 1a** a rectangle barrel, and is attached to the traverse

device besides a graphic display. The traverse device is supporting the 1st sounding tube 11 to the parting plane 1a, enabling free movement in a parallel direction and a vertical direction, where the normal line direction of the outside surface (parting plane 1a) of the vibrating wall 1 is met. Length L of the sounding tube 11 is set as 40 mm so that the sound pressure in the sounding tube 11 may not be influenced by surroundings lump. The distance Ln from the opening 11a of the sounding tube 11 to the microphone 13 is set as 30 mm so that the radiation sound from the vibrating wall 1 (parting plane 1a) may serve as a plane wave certainly.

0043 Measurement of the radiation sound from the vibrating wall 1 moved the 1st sounding tube 11 to each parting plane 1a with a traverse device, and was performed by measuring the sound pressure Pi in the sounding tube 11 with the microphone 13 on the basis of the input voltage E from the power amplification 39 to the loudspeaker 33. Under the present circumstances, the position of the sounding tube 11 to each parting plane 1a was adjusted so that the sounding tube 11 might be arranged along the normal line direction of each parting plane 1a and the opening 11a of the end of the sounding tube 11 might estrange only the prescribed distance h from each parting plane 1a. About this distance h, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0044 Simultaneously, for comparison with the result obtained by this experiment, the reflection type besides a graphic display was stuck on each parting plane 1a, and the velocity of vibration was measured, adjusting an optic axis to each parting plane 1a of every using the noncontact laser vibration meter (LDV) 37. LDV37 was used in order to eliminate the influence of the mass by an accelerometer.

0045 As shown in drawing 5 (b), in the 2nd sound pressure measuring device 5 used for the experiment, the support plate 21 is formed with iron material with a thickness of 30 mm which has sufficient rigidity. The microphone 23 is embedded at the support plate 21 so that it may be located on the outside surface of the support plate 21 in which the sound-collecting part carries out for relativity to the opening 15a of the end of the 2nd sounding tube 15. The 2nd sounding tube 15 has the 1st size and shape almost equal to the sounding tube 11, and it is arranged so that the normal line direction of opposite Perilla frutescens (L.) Britton var. crispa (Thunb.) Decne. may be met at the support plate 21. The area of the diaphragm besides the graphic display of the loudspeaker 19 in the 2nd sounding tube 15 is beforehand set as the prescribed area S0.

0046 Measurement of the radiation sound from the loudspeaker 19 was performed by measuring the sound pressure P0 of the radiation sound from the loudspeaker 19 with the microphone 23 on the basis of the input voltage e from the power amplification 43 to the loudspeaker 19. About the distance h along said normal line direction of the microphone 23 and the opening 15a of the sounding tube 15, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0047 Simultaneously, it measured by LDV besides a graphic display of the velocity of vibration V0 of the diaphragm besides the graphic display in the loudspeaker 19. Having used LDV has the dramatically small mass of a diaphragm, and it is easy to generate partial vibration and rolling in response to the influence by the weight in a contact type.

0048 The sound pressure Pi of the radiation sound from the loudspeaker 19 measured with the microphone 23 is inputted into the high speed operation device (FFT) 41 as the operation part 7. The velocity of vibration Vi measured by the area Si and LDV of the diaphragm 17 is beforehand inputted into FFT41, and is memorized, and the propagation characteristic Hpi is computed and outputted to it at each distance h of every according to said formula (4) from Pi, Si, and Vi.

0049 The sound pressure P0 of the radiation sound from the parting plane 1a measured with the microphone 13 of the 1st sound pressure measuring device 3 is inputted into the high speed operation device (FFT) 35 as the operation part 9. The propagation characteristic Hpi computed by FFT41 and the area S0 of the parting plane 1a are beforehand inputted into FFT35, and are memorized, The volume velocity Q0 is computed by every parting plane 1a according to these **P0** , Hpi, and S0 to said formula (5) and/or (6), and the aggregate value sigmaQ0 is outputted eventually. The velocity of vibration measured by LDV37 is also inputted into FFT35. In FFT35, by multiplying the velocity of vibration measured by LDV37 by the area S0 of the parting plane 1a, the theoretical value of the volume velocity in this experiment is computed by every parting plane 1a, and the aggregate value sigmaQt is outputted eventually.

0050 Next, the result of this experiment is explained based on drawing 6 - drawing 9.

0051 The propagation characteristic Hp of each distance h of every **which was outputted**

from FFT41 is expressed to drawing 6. It was checked that a level also increases, when the frequency characteristic showed the identical trend and its distance h increased, although there was a level difference by the distance h as shown in drawing 6.
0052 The aggregate value (experimental value) sigmaQ0 of the volume velocity characteristic computed in drawing 7 - drawing 9 at every parting plane 1a using the above-mentioned expression of relations (5) based on a reciprocity theorem, Aggregate value (theoretical value) sigmaQn of the volume velocity characteristic for which every parting plane 1a was asked from the velocity of vibration measured directly is similarly expressed with LDV37 to each distance (h= 1 mm, 5 mm, 15 mm) of every **between the rectangular vibrating wall 1 and the sounding tube 11 which are sound sources** . In drawing 7 - drawing 9, the experimental value sigmaQ0 is a dashed line, and theoretical-value sigmaQn is expressed as the solid line, respectively.
0053 In this experiment, it was checked that the measuring time for calculating the experimental value sigmaQ0 can be shortened about to 1/5 compared with the measuring time (measuring time for calculating theoretical-value sigmaQn) which used LDV37.
0054 As shown in drawing 7, in the case of h= 1 mm of distance, each peak and a level were in agreement good to 1 kHz, and it was checked that the difference is less than about **3 dB.
0055 As shown in drawing 8, in the case of h= 5-mm distance, there was a difference of 4-5 dB below 300 Hz, but in other fields, it was checked to 1 kHz that the difference is less than about **3 dB.
0056 As shown in drawing 9, in the case of h= 15-mm distance, the peak up to 1 kHz was mostly in agreement, but on the whole, the level produced a difference of +5-+10 dB, and it was checked that especially the difference in 500 Hz or less is large.
0057 It was checked by the above experimental result by the reciprocity theorem that the propagation characteristic Hpi which includes the sounding tube 15 from the vibrating wall 1 can be searched for with sufficient accuracy by the simple method using the sounding tube 15 and the microphone 23.
0058 It was checked by using the propagation characteristic Hpi searched for and the sound pressure P0 measured with the sounding tube 11 that it can ask for the volume velocity characteristic of a vibrating structure with sufficient accuracy simple.

Brief Description of the Drawings
Drawing 1 Drawing 1 (a) is a mimetic diagram of the 1st sound pressure measuring device of this embodiment, and drawing 1 (b) is a mimetic diagram of the 2nd sound pressure measuring device of this embodiment.
Drawing 2 Drawing 2 (a) is a mimetic diagram showing the state where there is no 1st sounding tube, and a mimetic diagram showing the state where drawing 2 (b) has the 1st sounding tube.
Drawing 3 The sectional view and drawing 3 (b) in which the state where drawing 3 (a) stuck silencing materials on the inner skin of a cylindrical sounding tube is shown are a sectional view showing the state where silencing materials were stuck on the inner surface of a rectangle barrel-like sounding tube.
Drawing 4 The other end is a sectional view showing the sounding tube blockaded with silencing materials.
Drawing 5 The mimetic diagram of the experimental device corresponding to drawing 1 (a) in drawing 5 (a) and drawing 5 (b) are the mimetic diagrams of the experimental device corresponding to drawing 1 (b).
Drawing 6 It is a figure showing the propagation characteristic of each distance h of every **which was called for by the experiment concerning this embodiment** .
Drawing 7 It is a figure showing the experimental value and theoretical value of an aggregate value of the volume velocity characteristic in the case of h= 1 mm of distance.
Drawing 8 It is a figure showing the experimental value and theoretical value of an aggregate value of the volume velocity characteristic in the case of h= 5-mm distance.
Drawing 9 It is a figure showing the experimental value and theoretical value of an aggregate value of the volume velocity characteristic in the case of h= 15-mm distance.
Description of Notations
1 Vibrating wall
1a The parting plane of a vibrating wall (measured plane)

3 The 1st sound pressure measuring device
5 The 2nd sound pressure measuring device
7 Operation part
9 Operation part
11 The 1st sounding tube
13 Microphone (1st sound pressure test section)
15 The 2nd sounding tube
17 Diaphragm
19 Loudspeaker
23 Microphone (2nd sound pressure test section)

Drawing 1

For drawings please refer to the original document.

Drawing 2

For drawings please refer to the original document.

Drawing 3

For drawings please refer to the original document.

Drawing 4

For drawings please refer to the original document.

Drawing 6

For drawings please refer to the original document.

Drawing 5

For drawings please refer to the original document.

Drawing 7

For drawings please refer to the original document.

Drawing 8

For drawings please refer to the original document.

Drawing 9

For drawings please refer to the original document.

For drawings please refer to the original document.

--- **Written amendment**

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Amendment 1
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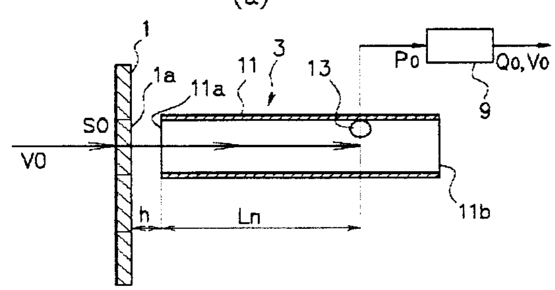
(54)【発明の名称】　振動計測方法及び振動計測システム

(57)【要約】　（修正有）

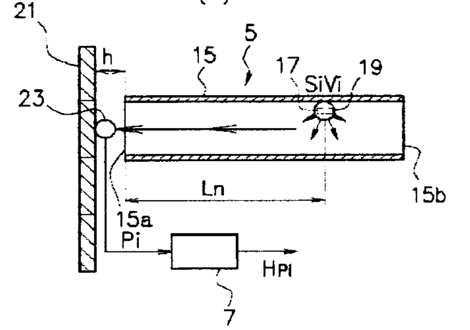
【課題】　簡単な設備で、被測定面近傍の音源の影響を排除することができ、且つ短時間で測定可能な非接触による振動計測方法の提供。

【解決手段】　第１の音響管１１を開口１１ａが被測定面１ａから距離ｈだけ離間するように配置し、第１の音響管１１内で開口１１ａから所定距離Ｌｎだけ離間した位置にて被測定面１ａから発せられる音の音圧Ｐ０を測定し、所定面積Ｓｉを有し振動速度Ｖｉで振動する振動板１７を、第１の音響管１１とほぼ等しい伝搬特性を発揮し得る第２の音響管１５内に開口１５ａから所定距離Ｌｎだけ離間するように配置し、第２の音響管１５外で開口１５ａと対向し且つ開口１５ａから所定距離ｈだけ離間する位置にて振動板１７から発せられる音の音圧Ｐｉを測定し、面積Ｓｉと振動速度Ｖｉと音圧Ｐｉとから$Hpi = Si \times Vi / Pi$に従って伝搬特性Hpiを算出し、該伝搬特性Hpiと音圧Ｐ０とから$V0 = P0 \times Hpi$に従って被測定面の体積速度Ｑ０を算出する。

(a)



(b)



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【特許請求の範囲】

【請求項１】　一端に開口を有する第１の音響管を該開口が被測定面から所定距離ｈだけ離間するように配置し、

前記第１の音響管内で前記開口から所定距離Ｌｎ だけ離間した位置にて前記被測定面から発せられる音の音圧Ｐ０ を測定し、

所定面積Ｓｉ を有し振動速度Ｖｉ で振動する振動板を、一端に開口を有し前記第１の音響管とほぼ等しい伝搬特性を発揮し得る第２の音響管内に前記開口から前記所定距離Ｌｎ だけ離間するように配置し、

前記第２の音響管外で前記開口と対向し且つ該開口から前記所定距離ｈだけ離間する位置にて前記振動板から発せられる音の音圧Ｐｉ を測定し、

前記面積Ｓｉ と振動速度Ｖｉ と音圧Ｐｉ とから次式

$$Hpi = Si \times Vi / Pi$$

に従って伝搬特性Hpiを算出し、

前記伝搬特性Hpiと音圧Ｐ０ とから次式

$$Q0 = P0 \times Hpi$$

に従って被測定面の体積速度Q0 を算出することを特徴とする振動計測方法。

【請求項２】　請求項１に記載の振動計測方法であって、

前記第１の音響管の他端は、閉塞されていることを特徴とする振動計測方法。

【請求項３】　請求項１又は請求項２に記載の振動計測方法であって、

前記第１及び第２の音響管の各内周面上の少なくとも一部には、吸音材が配置されていることを特徴とする振動計測方法。

【請求項４】　一端に開口を有し該開口が被測定面から所定距離ｈだけ離間するように配置された第１の音響管と、前記開口から所定距離Ｌｎ だけ離間するように前記第１の音響管内に配置され前記被測定面から発せられる音の音圧Ｐ0を測定する第１の音圧測定部と、を有する第１の音圧測定装置と、

一端に開口を有し前記第１音響管とほぼ等しい伝搬特性を発揮し得る第２の音響管と、前記開口から前記所定距離Ｌｎ だけ離間するように前記第２の音響管内に配置され所定面積Ｓｉ を有し振動速度Ｖｉ で振動する振動板と、前記開口から前記所定距離ｈだけ離間した位置で該開口と対向するように前記第２の音響管外に配置され前記振動板から発せられる音の音圧Ｐｉ を測定する第２の音圧測定部と、を有する第２の音圧測定装置と、

前記面積Ｓｉ と振動速度Ｖｉ と音圧Ｐｉ とから次式

$$Hpi = Si \times Vi / Pi$$

に従って伝搬特性Hpiを算出し、該伝搬特性Hpiと音圧Ｐ０ とから次式

$$V0 = P0 \times Hpi$$

に従って被測定面の体積速度Q0 を算出する演算部と、

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を備えたことを特徴とする振動計測システム。

【請求項５】　請求項４に記載の振動計測システムであって、

前記第１の音響管の他端は、閉塞されていることを特徴とする振動計測システム。

【請求項６】　請求項４又は請求項５に記載の振動計測システムであって、

前記第１及び第２の音響管の各内周面上の少なくとも一部には、吸音材が配置されていることを特徴とする振動計測システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、構造体の表面振動を計測する方法及び装置に関する。

【０００２】

【従来の技術】一般に構造物の振動を計測するには、加速度計が広く用いられている。しかし、騒音の発生し易い薄板構造の表面振動の計測やスピーカの振動面の計測などのように質量の小さい部分の振動を計測する場合、小型の加速度計を用いてもその質量が計測値に影響を与えてしまうという不都合があった。

【０００３】これに対し、振動速度を非接触で求める手法によれば、質量の小さい部分の振動計測を正確に行うことが可能である。このような手法として、レーザー・ドップラー速度計（ＬＤＶ）を用いる方法や、音響インテンシティ法や、音響ホログラフィ法などが知られている。

【０００４】

【発明が解決しようとする課題】音響インテンシティ法は、広く利用されており、粒子速度計測法としても良く知られているが、被測定部分の近傍に強い音源が存在すると、その影響を受けやすく計測誤差が増大する可能性が高いという問題がある。また、ＬＤＶを用いる方法や音響ホログラフィ法では、設備が大掛かりで高価であるという不都合があり、特にＬＤＶを用いる方法では、被測定部分の反射率の変化や形状の影響を受け易く、調整時間を含めた測定時間に多大な時間を要するという問題もある。

【０００５】本発明は上記の実情に鑑みてなされたものであって、大掛かりな設備を必要とせず、被測定面近傍の音源の影響を排除することができ、且つ短時間で測定可能な非接触による構造体の振動計測方法及び振動計速システムの提供を目的とするものである。

【０００６】

【課題を解決するための手段】上記目的を達成すべく、本発明に係る振動計測方法は、一端に開口を有する第１の音響管を該開口が被測定面から所定距離ｈだけ離間するように配置し、前記第１の音響管内で前記開口から所定距離Ｌｎ だけ離間した位置にて前記被測定面から発せられる音の音圧Ｐ０ を測定し、所定面積Ｓｉ を有し振動

速度Ｖｉ で振動する振動板を、一端に開口を有し前記第１の音響管とほぼ等しい伝搬特性を発揮し得る第２の音響管内に前記開口から前記所定距離Ｌｎ だけ離間するように配置し、前記第２の音響管外で前記開口と対向し且つ該開口から前記所定距離ｈだけ離間する位置にて前記振動板から発せられる音の音圧Ｐｉ を測定し、前記面積Ｓｉ と振動速度Ｖｉ と音圧Ｐｉ とから次式

$Hpi = Si \times Vi / Pi$

に従って伝搬特性Hpiを算出し、該伝搬特性Hpiと音圧Ｐ0 とから次式

$V0 = P0 \times Hpi$

に従って被測定面の体積速度Ｑ0 を算出するものである。

【０００７】本発明に係る振動計測システムは、第１の音圧測定装置と、第２の音圧測定装置と、演算部とを備えている。

【０００８】前記第１の音圧測定装置は、一端に開口を有し該開口が被測定面から所定距離ｈだけ離間するように配置された第１の音響管と、前記開口から所定距離Ｌｎ だけ離間するように前記第１の音響管内に配置され前記被測定面から発せられる音の音圧Ｐ0 を測定する第１の音圧測定部と、を有する。前記第２の音圧測定装置は、一端に開口を有し前記第１の音響管とほぼ等しい伝搬特性を発揮し得る第２の音響管と、前記開口から前記所定距離Ｌｎ だけ離間するように前記第２の音響管内に配置され所定面積Ｓｉ を有し振動速度Ｖｉ で振動する振動板と、前記開口から前記所定距離ｈだけ離間した位置で該開口と対向するように前記第２の音響管外に配置され前記振動板から発せられる音の音圧Ｐｉ を測定する第２の音圧測定部と、を有する。前記演算部は、前記面積Ｓｉ と振動速度Ｖｉ と音圧Ｐｉ とから次式

$Hpi = Si \times Vi / Pi$

に従って伝搬特性Hpiを算出し、該伝搬特性Hpiと音圧Ｐ0 とから次式

$V0 = P0 \times Hpi$

に従って被測定面の体積速度Ｑ0 を算出する。

【０００９】上記計測方法及び計測システムによれば、被測定面に対して非接触状態で被測定面の体積速度Ｑ0 が求められる。また、構造上大きな装置を含まないため大掛かりな設備を必要とせず、被測定面以外からの放射音は第１の音響管の外壁で反射されるので被測定面近傍の音源の影響を排除することができ、さらに、被測定面の反射率の変化や形状の影響を受け難く調整時間が不要であるため短時間で測定することができる。

【００１０】上記計測方法及び計測システムにおいて、前記第１の音響管の他端を閉塞しても良い。これにより、被測定面以外からの放射音の影響をさらに確実に排除することができ、測定精度が向上する。また、第２の音響管の他端を同様に閉塞しても良い。

【００１１】上記計測方法及び計測システムにおいて、前記第１及び第２の音響管の各内周面上の少なくとも一部に、吸音材を配置しても良い。これにより、第１及び第２の音響管内において共鳴の発生が抑制され、測定精度が向上する。

【００１２】上記測定方法及び測定システムにおいて、前記第１の音響管と前記第２の音響管とが共通する１つの音響管であっても良い。これにより、第１の音響管と第２の音響管とが確実に等しい伝搬特性を発揮し得るので、測定精度が向上する。また、複数の音響管を設ける必要がないので、システムの簡素化が図られる。

【００１３】上記測定方法及び測定システムにおいて、前記第１及び第２の音響管の断面積は、対象上限周波数に対して平面波となる面積よりも小さく設定されることが好ましい。これにより、被測定面及び振動板からの放射音はそれぞれ第１及び第２の音響管内を減衰することなく伝搬されるので、測定精度が向上する。

【００１４】上記測定方法及び測定システムにおいて、前記第２の音響管外で前記開口と対向し且つ該開口から前記所定距離ｈだけ離間する位置に剛性の高い部材の表面上で前記振動板から発せられる音の音圧Ｐｉ を測定しても良く、また、前記第１の音響管を前記被測定面の法線方向に沿って配置しても良い。

【００１５】さらに、被測定面の振動速度Ｖ0 を体積速度Ｑ0 と被測定面の面積Ｓ0 とから次式

$V0 = Q0 / S0$

に従って算出しても良い。

【００１６】

【発明の実施の形態】以下、本発明の一実施形態を、図面に基づいて説明する。

【００１７】図１（ａ）は本実施形態の第１の音圧測定装置の模式図、図１（ｂ）は本実施形態の第２の音圧測定装置の模式図、図２（ａ）は第１の音響管がない状態を示す模式図、図２（ｂ）は第１の音響管がある状態を示す模式図である。

【００１８】まず、本実施形態に係る計測システムの基本構成について説明する。

【００１９】図１（ａ）及び図１（ｂ）に示すように、本実施形態に係る計測システムは、第１の音圧測定装置３と、第２の音圧測定装置５と、演算部７，９とを備えている。

【００２０】測定対象である振動壁１の任意の分割面（被測定面）１ａは所定面積Ｓ0 を有し、第１の音圧測定装置３は第１の音響管１１と第１のマイクロホン（第１の音圧測定部）１３とを備えている。第１の音響管１１は、同一の断面形状がその中心軸に沿って直線状に連続する金属又は樹脂製の筒状体であり、その両端には前記断面形状を呈する開口１１ａ，１１ｂが形成されている。第１の音響管１１は分割面１ａの法線方向に沿って配置され、一端の開口１１ａは分割面１ａから所定距離ｈだけ離間している。マイクロホン１３は、開口１ａか

ら中心軸に沿って所定距離Ｌｎ だけ離間するように第１の音響管１１内に配置され、分割面１ａから発せられる音の音圧Ｐ0 を測定して演算部９へ出力する。演算部９は、後述する方法によって体積速度Ｑ0 及び／又は振動速度Ｖ0 を算出し出力する。

【００２１】第２の音圧測定装置５は、第２の音響管１５と、振動板１７を有するスピーカ１９と、剛性の高い支持板２１と、第２のマイクロホン（第２の音圧測定部）２３とを備えている。

【００２２】第２の音響管１５は、第１の音響管１１と同様に、同一の断面形状がその中心軸に沿って直線状に連続する金属又は樹脂製の筒状体であり、その両端には前記断面形状を呈する開口１５ａ，１５ｂが形成されている。第２の音響管１５は、第１の音響管１１とほぼ等しい伝搬特性を発揮し得るように、第１の音響管１１とほぼ等しい形状、大きさ、及び材質を有している。なお、これらの要素は必ずしも同一である必要はなく、例えば遮音性が極めて高い状態が得られれば両者の材質は相違していても構わない。

【００２３】振動板１７は、一端の開口１５ａから中心軸に沿って所定距離Ｌｎ だけ離間するように第２の音響管１５内に配置されている。振動板１７は、所定面積Ｓｉ を有し、振動速度Ｖｉ で振動する。支持板２１は、第２の音響管１５外で開口１５ａと対向し且つ開口１５ａから所定距離ｈだけ離間する位置に、第２の音響管１５の中心軸に対してほぼ垂直に配置されている。マイクロホン２３は、開口１５ａから所定距離ｈだけ離間した位置で支持板２１の外面上に固定され、振動板１７から発せられる音の音圧Ｐｉ を測定して演算部７へ出力する。演算部７は、後述する方法によって伝搬特性Hpiを算出し出力する。

【００２４】このように、第１の音圧測定装置３と第２の音圧測定装置５とは、音の伝搬特性に関して等価に構成されている。

【００２５】次に、本実施形態に係る計測方法について説明する。

【００２６】第１の音圧測定装置３と第２の音圧測定装置５とは、音の伝搬特性に関して等価に構成されているため、相反定理から、分割面１ａの体積速度Ｑ0 、マイクロホン１３によって検出される音圧Ｐ0 、振動板１７の体積速度Ｑｉ 、マイクロホン２３によって検出される音圧Ｐｉ 、及び伝搬特性Hpiとの間には、次式（１）の関係が成立する。

【００２７】$Q_0 / P_0 = Q_i / P_i = H_{pi}$　…（１）

ここで、体積速度Ｑ0 は、分割面１ａの面積Ｓ0 及び振動速度Ｖ0 により、体積速度Ｑｉ は、振動板１７の面積Ｓｉ 及び振動速度Ｖｉ により、それぞれ次式（２），（３）に従って求められる。

【００２８】$Q_0 = S_0 \times V_0$　…（２）

$Q_i = S_i \times V_i$　…（３）

従って、式（１），（２），（３）から、次式（４），（５），（６）が求められる。

【００２９】$H_{pi} = S_i \times V_i / P_i$　…（４）

$Q_0 = P_0 \times H_{pi}$　…（５）

$V_0 = P_0 \times H_{pi} / S_0$　…（６）

分割面１ａから放射される音の体積速度Ｑ0 及び／又は振動速度Ｖ0 を測定する場合、まず、第２の音圧測定装置５が使用され、スピーカ１９（振動板１７）から放射される音の音圧Ｐｉ がマイクロホン２３によって検出されて演算部７へ入力される。演算部７には、振動板１７の面積Ｓｉ 及び振動速度Ｖｉ が予め入力され記憶されており、これらＰｉ，Ｓｉ，Ｖｉ から式（４）に従って伝搬特性Hpiが算出される。

【００３０】次に、第１の音圧測定装置３が使用され、分割面１ａから放射される音の音圧Ｐ0 がマイクロホン１３によって検出されて演算部９へ入力される。演算部９には、演算部７によって算出された伝搬特性Hpi及び分割面１ａの面積Ｓ0 が予め入力され記憶されており、これらＰ0，Hpi，Ｓ0 から式（５）及び／又は（６）に従って分割面１ａの体積速度Ｑ0 及び／又は振動速度Ｖ0 が算出される。なお、体積速度Ｑ0 のみが算出される場合には、分割面１ａの面積Ｓ0 は演算部９に入力されなくても良い。

【００３１】このような計測方法及び計測システムによれば、分割面１ａに対して非接触状態で分割面１ａの体積速度Ｑ0 及び／又は振動速度Ｖ0 を求めることができる。

【００３２】また、構造上大きな装置を含まないため、大掛かりな設備を必要とすることがない。

【００３３】また、分割面１ａ以外からの放射音は、第１の音響管１１の外壁で反射される。例えば、図２（ａ）に示すように、第１の音響管１１を設けない状態で、分割面１ａの近傍の音圧Ｐm をマイクロホン２５によって計測すると、検出される音圧Ｐm は隣接する分割面からの振動放射音Ｐｊ の漏れ込みの影響を受ける。このため、測定対象である分割面１ａのみからの放射音の検出が難しい。これに対し、図２（ｂ）に示すように、第１の音響管１１を設けた状態では、分割面１ａ以外からの放射音は第１の音響管１１の外壁で反射され、分割面１ａの振動速度Ｖ0 に応じた平面波のみが音響管１１の内部に伝搬され、マイクロホン１１によってその音圧Ｐ0 を計測することができる。すなわち、分割面１ａ近傍の音源の影響を排除することができる。

【００３４】さらに、被測定面（分割面１ａ）の反射率の変化や形状の影響を受け難く調整時間が不要であるため、極めて短時間で測定することができる。

【００３５】なお、第１の音響管１１及び第２の音響管１５の断面形状は、特に限定されるものではなく、円形、矩形等の様々な形状が適用され得る。

【００３６】また、第１の音響管１１と第２の音響管１

５とは、共通する１つの音響管であっても良い。これにより、第１の音響管と第２の音響管とが確実に等しい伝搬特性を発揮し得るので、測定精度が向上する。また、複数の音響管を設ける必要がないので、システムの簡素化が図られる。

【００３７】また、第１及び第２の音響管１１，１５の断面積は、対象上限周波数に対して平面波となる面積よりも小さく設定されていること、例えば、第１及び第２の音響管１１，１５の内周面の断面形状が分割面１ａの外周縁とほぼ等しい形状又はこの形状を完全に内側に含む大きさ及び形状に設定されていることが好ましい。これにより、分割面１１ａ及び振動板１７からの放射音はそれぞれ第１及び第２の音響管１１，１５内を減衰することなく伝搬されるので、測定精度が向上する。

【００３８】また、第１及び第２の音響管１１，１５の各内周面上に吸音材２７を貼着して配置することにより、第１及び第２の音響管１１，１５内において共鳴の発生が抑制され、測定精度が向上する。共鳴の抑制効果は、第１及び第２の音響管１１，１５の各内周面の全域に設けられていなくても発揮され、例えば、音響管１１，１５が円筒状の場合は図３（ａ）に示すように半周の領域に設ければその効果が十分に得られ、矩形筒状の場合は図３（ｂ）に示すように４箇所の内面のうち１箇所の内面全域に設ければその効果が十分に得られる。なお、第２の音響管１５の構成は第１の音響管１１とほぼ同様であるため、その図示を省略している。

【００３９】さらに、第１の音響管１１の他端１１ｂを閉塞することにより、分割面１ａ以外からの放射音の影響をさらに確実に排除することができ、測定精度が向上する。この場合、他端１１ｂを音響管１１と一体的に形成された蓋体等によって閉塞することも可能であるが、図４に示すように吸音材２９によって閉塞する方がより好ましく、さらに内周面上の吸音材２７と共に設けることが最も好ましい。また、第２の音響管１５の他端１５ｂを同様に閉塞することにより、第２の音響管１５においても外部から影響を排除することができる。

【００４０】次に、本実施形態に係る計測システムを用いた行った実験について説明する。

【００４１】図５（ａ）に示すように、実験で使用された第１の音圧測定装置３では、騒音源である振動壁１は、厚さ２㎜の鉄板により矩形板体状に形成され、支持台３１に固定されている。支持台３１は、一面に開放面を有する箱体状に形成され、開放面が水平方向を向くように配置されている。振動壁１は、支持台３１の開放面を閉塞するように開放面の周縁部分に複数のボルトによって締結されている。スピーカ３３は、支持台３１内の振動壁１と相対向する面上に固定されている。支持台３１は、スピーカ３３から放射された音が音響加振により振動壁１のみから放射されるように、十分な厚さ１０㎜を有する鉄板によって形成されている。音源である振動壁１の外面は２０分割（縦４列×横５列）され、一つの分割面１ａは８０㎜×８０㎜の略正方形に設定されている。

【００４２】第１の音響管１１は、分割面１ａとほぼ等しい断面形状及び大きさを有する矩形筒体状に形成され、図示外のトラバース装置に取り付けられている。トラバース装置は、第１の音響管１１を、振動壁１の外面（分割面１ａ）の法線方向に沿った状態で分割面１ａに対して平行な方向及び垂直な方向に移動自在に支持している。音響管１１の長さＬは、音響管１１内の音圧が廻り込みの影響を受けないように４０㎜に設定されている。また、音響管１１の開口１１ａからマイクロホン１３までの距離Ｌｎ は、振動壁１（分割面１ａ）からの放射音が確実に平面波となるように３０㎜に設定されている。

【００４３】振動壁１からの放射音の計測は、トラバース装置によって第１の音響管１１を各分割面１ａに対して移動させ、パワーアンプ３９からスピーカ３３への入力電圧Ｅを基準に音響管１１内の音圧Ｐｉ をマイクロホン１３で計測することにより行った。この際、各分割面１ａに対する音響管１１の位置は、音響管１１が各分割面１ａの法線方向に沿って配置され且つ音響管１１の一端の開口１１ａが各分割面１ａから所定距離ｈだけ離間するように調整した。この距離ｈに関しては、１㎜，５ｍｍ，１５㎜の３条件について計測した。

【００４４】同時に、本実験により得られた結果との比較のため、各分割面１ａに図示外の反射テープを貼付し、非接触型のレーザ振動計（ＬＤＶ）３７を用いて各分割面１ａ毎に光軸の調整を行いながら振動速度の計測を行った。ＬＤＶ３７を用いたのは、加速度計による質量の影響を排除するためである。

【００４５】図５（ｂ）に示すように、実験に使用された第２の音圧測定装置５では、支持板２１が、十分な剛性を有する厚さ３０㎜の鉄材で形成されている。マイクロホン２３は、その集音部が第２の音響管１５の一端の開口１５ａと相対向する支持板２１の外面上に位置するように、支持板２１に埋め込まれている。第２の音響管１５は第１の音響管１１とほぼ等しい大きさ及び形状を有し、支持板２１に対しその法線方向に沿うように配置されている。第２の音響管１５内のスピーカ１９の図示外の振動板の面積は、予め所定面積Ｓ0 に設定されている。

【００４６】スピーカ１９からの放射音の計測は、スピーカ１９からの放射音の音圧Ｐ0 をパワーアンプ４３からスピーカ１９への入力電圧ｅを基準にマイクロホン２３で計測することにより行った。マイクロホン２３と音響管１５の開口１５ａとの前記法線方向に沿った距離ｈに関しては、１㎜，５㎜，１５㎜の３条件について計測した。

【００４７】同時に、スピーカ１９内の図示外の振動板

の振動速度$V0$ を図示外のＬＤＶによって計測した。ＬＤＶを用いたのは、振動板の質量が非常に小さく、接触型ではその重さによる影響を受けて分割振動やローリングが発生し易いためである。

【００４８】マイクロホン２３により計測されたスピーカ１９からの放射音の音圧Pi は、演算部７としての高速演算装置（ＦＦＴ）４１へ入力される。ＦＦＴ４１には、振動板１７の面積Si 及びＬＤＶにより計測された振動速度Vi が予め入力され記憶されており、Pi ，Si ，Vi から前記式（４）に従って各距離ｈ毎に伝搬特性Hpiが算出され、出力される。

【００４９】第１の音圧測定装置３のマイクロホン１３により計測された分割面１ａからの放射音の音圧$P0$ は、演算部９としての高速演算装置（ＦＦＴ）３５へ入力される。ＦＦＴ３５には、ＦＦＴ４１によって算出された伝搬特性Hpi及び分割面１ａの面積$S0$ が予め入力され記憶されており、これら$P0$ ，Hpi，$S0$ から前記式（５）及び／又は（６）に従って体積速度$Q0$ が分割面１ａ毎に算出され、最終的にその加算値$\Sigma Q0$ が出力される。また、ＬＤＶ３７により計測された振動速度もＦＦＴ３５へ入力される。ＦＦＴ３５では、ＬＤＶ３７により計測された振動速度に分割面１ａの面積$S0$ を乗じることにより本実験における体積速度の理論値が分割面１ａ毎に算出され、最終的にその加算値ΣQt が出力される。

【００５０】次に、本実験の結果について、図６～図９に基づき説明する。

【００５１】図６には、ＦＦＴ４１から出力された各距離ｈ毎の伝搬特性Hp が表されている。図６に示されるように、距離ｈによるレベル差はあるものの、周波数特性は同一傾向を示し、距離ｈが増えるとレベルも増加することが確認された。

【００５２】図７～図９には、相反定理に基づいた上記関係式（５）を用いて、分割面１ａ毎に算出した体積速度特性の加算値（実験値）$\Sigma Q0$ と、同様にＬＤＶ３７で直接的に計測した振動速度から分割面１ａ毎に求めた体積速度特性の加算値（理論値）ΣQn とが、音源である矩形の振動壁１と音響管１１との間の各距離（ｈ＝１㎜，５㎜，１５㎜）毎に表されている。なお、図７～図９において、実験値$\Sigma Q0$ は破線で、理論値ΣQn は実線でそれぞれ表示されている。

【００５３】また、本実験において、実験値$\Sigma Q0$ を求めるための計測時間は、ＬＤＶ３７を用いた計測時間（理論値ΣQn を求めるための計測時間）に比べて、１／５程度に短縮可能であることが確認された。

【００５４】図７に示すように、距離ｈ＝１㎜の場合は、１ＫＨｚまで各ピーク及びレベルが良好に一致し、その差がほぼ±３ｄＢ以内であることが確認された。

【００５５】図８に示すように、距離ｈ＝５㎜の場合は、３００Ｈｚ以下で４～５ｄＢの差があるが、その他の領域では１ＫＨｚまでその差がほぼ±３ｄＢ以内であることが確認された。

【００５６】図９に示すように、距離ｈ＝１５㎜の場合は、１ＫＨｚまでのピークはほぼ一致するが、レベルは全体的に＋５～＋１０ｄＢの差を生じ、特に５００Ｈｚ以下での差が大きいことが確認された。

【００５７】以上の実験結果により、相反定理により音響管１５とマイクロホン２３を用いた簡便な方法により、振動壁１から音響管１５を含めた伝搬特性Hpiを精度良く求めることができることが確認された。

【００５８】また、求めた伝搬特性Hpiと音響管１１で計測した音圧$P0$ とを用いることにより、振動構造物の体積速度特性を精度良く簡便に求めることができることが確認された。

【００５９】

【発明の効果】以上説明したように、本発明に係る計測方法及び計測システムによれば、被測定面に対して非接触状態で被測定面の体積速度$Q0$ が求められる。また、構造上大きな装置を含まないため大掛かりな設備を必要とせず、被測定面以外からの放射音は第１の音響管の外壁で反射されるので被測定面近傍の音源の影響を排除することができ、さらに、被測定面の反射率の変化や形状の影響を受け難く調整時間が不要であるため短時間で測定することができる。

【図面の簡単な説明】

【図１】図１（ａ）は本実施形態の第１の音圧測定装置の模式図、図１（ｂ）は本実施形態の第２の音圧測定装置の模式図である。

【図２】図２（ａ）は第１の音響管がない状態を示す模式図、図２（ｂ）は第１の音響管がある状態を示す模式図である。

【図３】図３（ａ）は円筒状の音響管の内周面に消音材を貼着した状態を示す断面図、図３（ｂ）は矩形筒体状の音響管の内面に消音材を貼着した状態を示す断面図である。

【図４】他端が消音材で閉塞された音響管を示す断面図である。

【図５】図５（ａ）は図１（ａ）に対応する実験装置の模式図、図５（ｂ）は図１（ｂ）に対応する実験装置の模式図である。

【図６】本実施形態に係る実験により求められた各距離ｈ毎の伝搬特性を表わす図である。

【図７】距離ｈ＝１㎜の場合における体積速度特性の加算値の実験値と理論値とを表す図である。

【図８】距離ｈ＝５㎜の場合における体積速度特性の加算値の実験値と理論値とを表す図である。

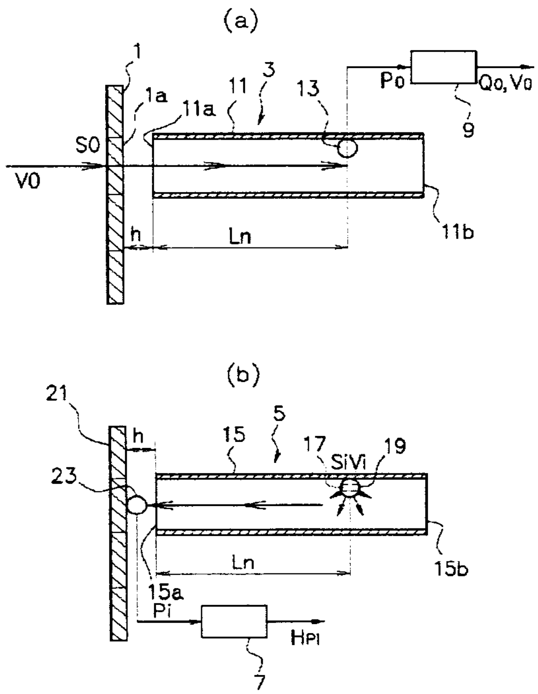
【図９】距離ｈ＝１５㎜の場合における体積速度特性の加算値の実験値と理論値とを表す図である。

【符号の説明】

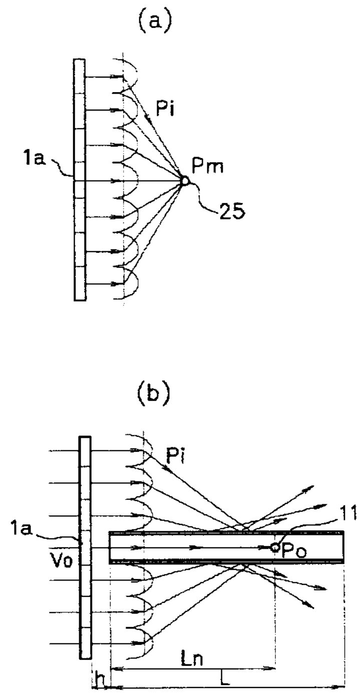
１　振動壁

１ａ　振動壁の分割面（被測定面）
３　第１の音圧測定装置
５　第２の音圧測定装置
７　演算部
９　演算部
１１　第１の音響管
１３　マイクロホン（第１の音圧測定部）
１５　第２の音響管
１７　振動板
１９　スピーカ
２３　マイクロホン（第２の音圧測定部）

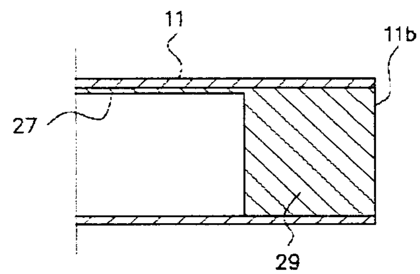
【図１】



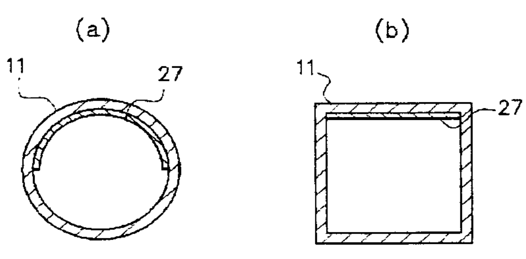
【図２】



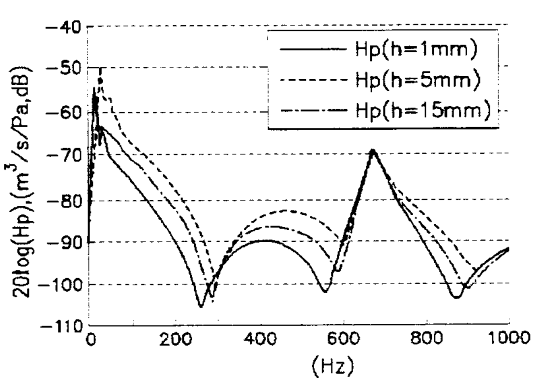
【図４】



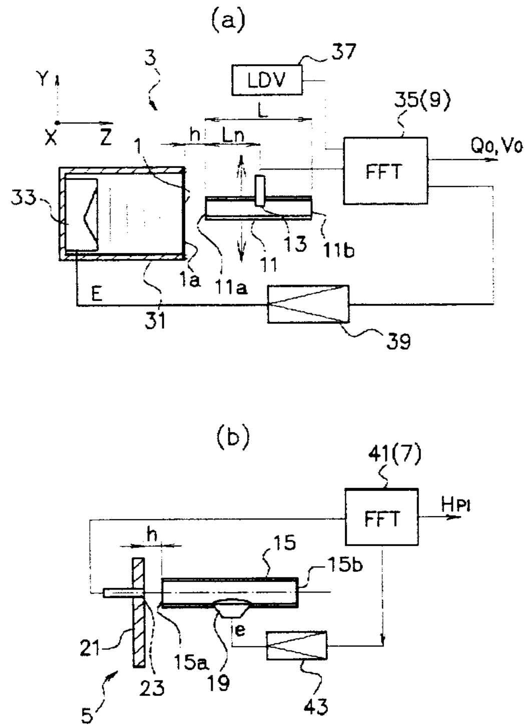
【図３】



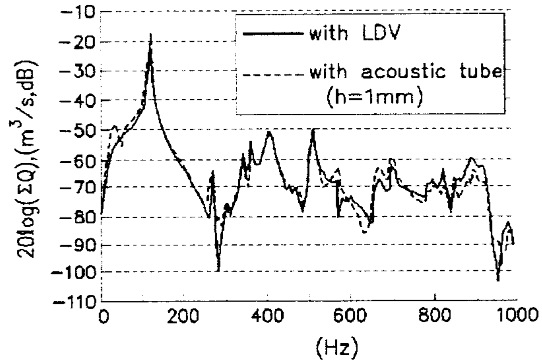
【図６】



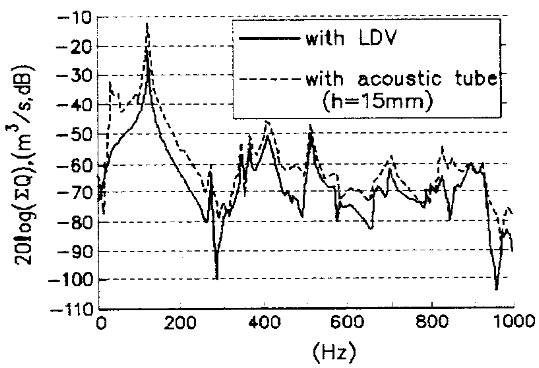
【図５】



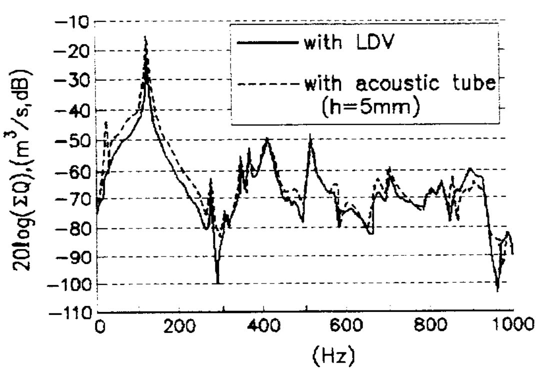
【図７】



【図９】



【図８】



【手続補正書】

【提出日】平成１３年１月９日（２００１．１．９）

【手続補正１】

【補正対象書類名】明細書

【補正対象項目名】発明の名称

【補正方法】変更

【補正内容】

【発明の名称】　振動計測方法及び振動計測システム